

# Results of the application of satellite remote sensing methods for the development of a preliminary estimate of the main agricultural and horticultural crops

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## 240 thousand ha

The area of sugar beet determined on the experimental method of crop identification based on satellite imagery in 2020. Compared to the area of last year's crops, it is approximately 1% smaller, and also approximately 1% smaller than the area estimated by Central Statistical Office experts at the stage of preliminary estimation in 2020.

### Introduction

The application of modern methods of satellite image processing for the purposes of agricultural statistics is one of the innovative activities carried out by public statistics.

For many years now, the Department of Agriculture Statistics Poland and the Statistical Office in Olsztyn (specialization: agriculture) have been conducting studies on the application of satellite imagery for the purposes of forecasting agricultural and horticultural crop areas. The studies were conducted in cooperation with scientific entities, i.e. the Space Research Centre of the Polish Academy of Sciences (CBK PAN) as well as the Institute of Geodesy and Cartography (IGiK). Scientific entities have proper scientific facilities and IT infrastructure for the download and analysis of satellite images, while Statistics Poland has provided field materials in the form of a description of the crops on agricultural parcels (survey type: in-situ) for the validation of the obtained results. A project entitled "Satellite identification and monitoring of crops for the purposes of agricultural statistics – SATMIROL" is being carried out within the framework of the above works, as part of the 1st competition for open projects within the framework of the strategic programme of scientific research and development works, entitled: "Social and Economic Development of Poland in the Conditions of Globalizing Market – GOSPOSTRATEG". The aim of the research and development project is the creation and implementation of an innovative system for the identification and monitoring of agricultural crops. The monitoring will also cover the impact of crisis situations (droughts, floods, frosts, etc.) on the condition of agricultural crops during the vegetation period. The project constitutes a continuation of the activities carried out by Statistics Poland (GUS) and SRC, aimed at applying satellite data in agricultural research.

The following data will be used as part of project implementation: Earth Observation (EO) data from satellites Sentinel-1 and Sentinel-2, data from the administration and IT system of the Agency for the Restructuring and Modernisation of Agriculture (Agencja Restrukturyzacji i Modernizacji Rolnictwa - ARiMR), including data from the Land Parcel Identification system (LPIS), cadastral data from the Land and Building Register (Ewidencja Gruntów i Budynków - EGiB) as well as statistical data from the agricultural surveys conducted by GUS.

The Department of Agriculture of Statistics Poland also participates in a consortium with CBK PAN and IGiK in the project implemented in cooperation with the European Space Agency (ESA). Within the framework of the cooperation with ESA in the field of using satellite imagery for the purposes of identification and monitoring of crops, the Department of Agriculture has established close cooperation with the Agency for the Restructuring and Modernisation of Agriculture as well as the National Agricultural Support Centre. The main subject

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matter of the works is the identification of sown areas and determination of their surface area, as well as yielding of plants and monitoring of crisis situations occurring in the field of agriculture and affecting the harvest.

As a result of the occurrence of the coronavirus pandemic at the beginning of this year as well as reduction in representative surveys, works on the application of satellite images for the purposes of estimating the area of agricultural and horticultural crops have been intensified. Due to the fact that the National Agricultural Census will be conducted in the months of September to November 2020, it is necessary to estimate the areas of crops at an earlier stage in order to enable the determination of the expected harvest of agricultural and horticultural crops. Therefore, for the first time ever, the Department of Agriculture together with the Statistical Office in Olsztyn have used satellite imagery to estimate the areas of agricultural and horticultural crops.

For several years, official statistics have been conducting development work in the field of using remote sensing data for the purposes of agricultural statistics. In order to meet the growing expectations of the recipients of statistical data regarding the quality, detail and timeliness of data, this note presents the latest solutions in the field of using satellite remote sensing methods to determine the area of crops.

### Preliminary estimate of the main agricultural and horticultural crops in 2020.

The estimate was made using satellite remote sensing methods. The basis of its development was Sentinel-1A/B radar images (resolution 10m). The observation period covered the months of April-June 2020. A total of 248 satellite scenes with 250 km of GRD-IW (Ground Range Detected) data were used in co- and cross polarization (VV, VH). The estimate was developed on the basis of the segmentation and object based classification of the Sigma Nought backscattering coefficient using machine learning algorithms (Supported Vector Machine). The data from the vector database of applications for granting payments obtained by the Department of Agriculture of the Central Statistical Office from the Agency for Restructuring and Modernization of Agriculture was used to learn the system and validate the results of the classification. The overall classification accuracy was 79%. The detailed results of classification and accuracy obtained for individual crops is presented in the table below:

**Table 1. The detailed scope of classification and accuracy obtained for individual crops**

Cultivation	Area in [ha]	Precision*	Recall*	F-score*	OA*	KIA*		
sugar beets	239674	0.83	0.81	0.82	0.79	0.77		
charlock	239158	0.47	0.31	0.37				
buckwheat	211035	0.57	0.51	0.54				
spring barley	254351	0.81	0.77	0.79				
winter barley	255344	0.93	0.91	0.92				
maize	1463744	0.81	0.92	0.86				
cereal mixtures	303323	0.52	0.39	0.44				
oat	474007	0.57	0.69	0.62				
fruit tree plantations	619658	0.75	0.77	0.76				
fruit shrub plantations	581422	0.56	0.52	0.54				
millet	158618	0.61	0.55	0.58				
spring wheat	147610	0.61	0.29	0.40				
winter wheat	1731230	0.89	0.94	0.92				
spring triticale	730939	0.46	0.37	0.41				
winter triticale	1024497	0.79	0.87	0.83				
spring rape	18230	0.59	0.03	0.06				
winter rape	983171	0.93	0.99	0.96				
legumes	264083	0.69	0.62	0.65				
grasses and grasslands	4565123	0.86	0.94	0.90				
strawberry	171043	0.70	0.69	0.69				
tobacco	46314	0.81	0.81	0.81				
vegetables	206467	0.54	0.45	0.49				
potatoes	148306	0.82	0.78	0.80				
herbs and spices	135610	0.60	0.38	0.46				
rye	667746	0.84	0.88	0.86				
<b>Total</b>	<b>15640703</b>							

KIA - kappa coefficient was 0,77

\*Precision - ratio of correctly classified crops to the total number of classified objects in this class,

\*Recall - ratio of correctly classified crops to the total number of control objects in that class,

\*F-score - harmonic mean with precision and recall,

\*OA (overall accuracy) - overall accuracy expressing the quotient of the sum of correctly classified objects and the total number of all classified objects,

\*KIA - kappa coefficient - expresses the total classification error. This factor determines how much better the classification has been done compared to random assignment of values. The kappa coefficient can range from -1 to 1. A value of 0 indicates that the classification is no better than a random classification. A negative number indicates that the classification is much worse than a random one. A value close to 1 indicates that the classification is much better than a random one."

## Methodological notes and analysis of the results

a) In order to verify the obtained results, the area of crops in Poland and voivodeships recognized in 2020 was compared with the area recognized in 2019, assuming that unless there were significant losses in winter and permanent crops it should not change significantly.

**Table 2. Changes in the sown area in 2020 - in percentage**

Cultivation	Poland	In voivodeships
	2019=100	2019=100
winter wheat	94,9	76,1-116,6
spring wheat	50,9	9,4-79,5
winter triticale	99,1	84,9-189,8
spring triticale	219,5	69,1-309,5
winter rye	98,7	75,1-197,8
winter barley	126,3	75,8-147,4
spring barley	107,5	63,8-181,7
oat	130,9	94,4-221,9
cereal mixtures	64,7	9,2-103,5
cereals*	103,0	92,3-110,9
buckwheat	134,8	63,4-1062,4
millet	228,7	14,7-1177,7
maize	97,5	77,1-128,1
sugar beets	102,0	25,8-445,9
winter rape	108,7	89,6-215,8
spring rape	16,2	10,5-112,0
charlock	254,8	90,4-622,9
potatoes	87,7	42,8-112,1
tobacco	157,9	0-4351,9
legumes	108,2	46,6-186,0
vegetables	116,1	42,4-228,3
strawberry	148,8	79,6-533,1
herbs and spices	180,9	37,5-1107,6
grasses and grasslands	90,5	69,7-101,3
fruit tree plantations	104,4	66,4-246,2
fruit shrub plantations	82,4	44,5-554,1
<b>Total</b>	<b>99,9</b>	<b>99,7-100,8</b>

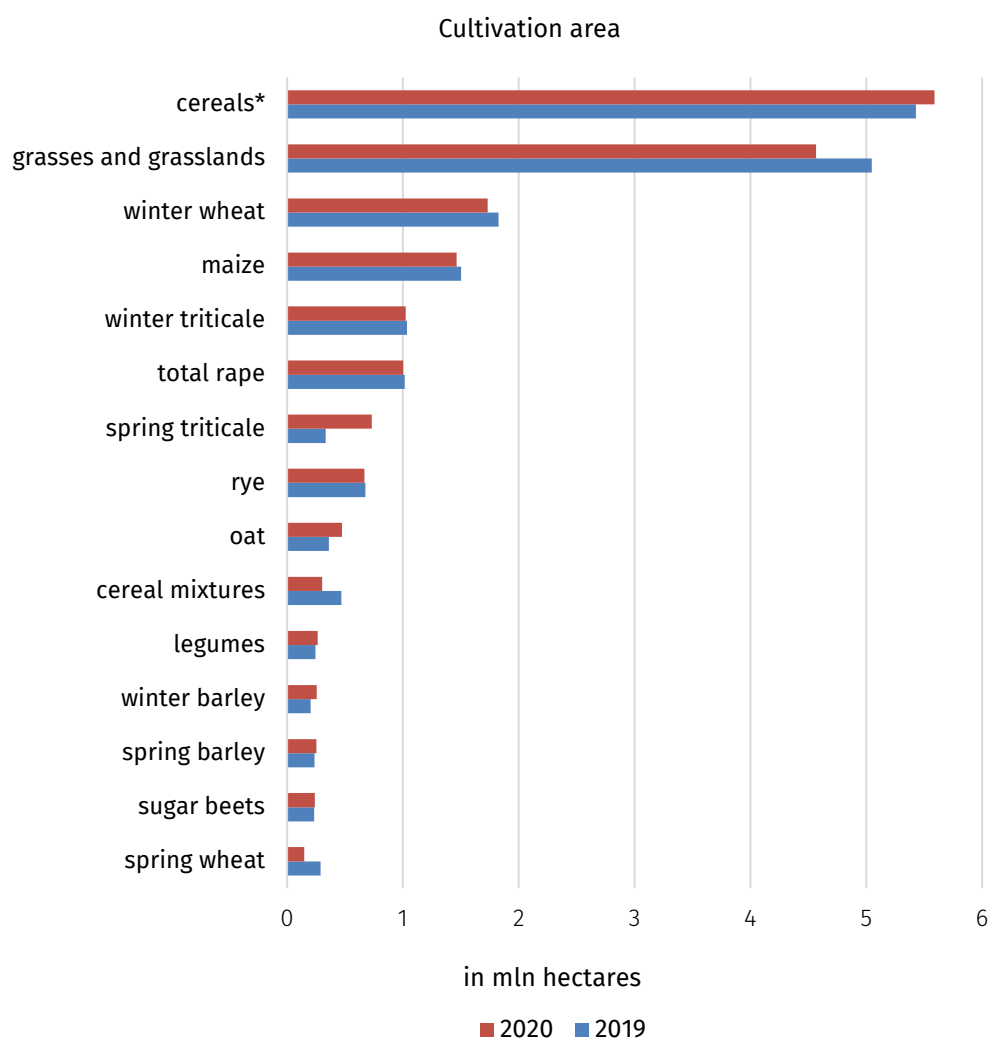
\* cereals - cereals similar in shape

Changes in the sown area  
Poland = **99,9%** (2019 = 100%)

1) There is a high compliance rate of 103.0% for a group of grains that are similar in conformation. They are dominated by winter crops, preferred by farmers due to spring droughts occurring in Poland. Spring crops usually appear after winter losses or are associated with the lack of time for sowing winter crops, difficulties in preparing fields. Accurate identification of winter crops at an early stage of development may be difficult due to the shifting autumn sowing dates and weaker development of these plants in the autumn and winter period and catch crops remaining in the field for the winter period. The recognition of spring cereals in pure sowing may be difficult due to their frequent occurrence in multi-species mixtures. The course of spring agrometeorological conditions determines the diversification of development, i.e. barley copes better in conditions of moisture deficiency, while oats, the species most often included in spring mixtures, develop faster in good moisture conditions.

- 2) The total area of maize is comparable - 97.5%.
- 3) On the national scale, a relatively stable area of winter rape cultivation is observed - 108.7%. Only in the Lublin Voivodeship, the area of this cultivation doubled. The cultivation of spring rape in Poland is of a marginal nature and here large fluctuations in the acreage are to be expected.
- 4) Sugar beets were cultivated in Poland on a similar area - 102.0%. Nevertheless, there are large changes in area at the level of some voivodeships. It is a highly specialized production, usually carried out on the same farms with specialized equipment, therefore less variation is expected. In general, a high accuracy of sugar beet classification based on control samples was obtained, which was 82.7%. The remaining 17.3% of the reference plots were classified as other crops (among others 4.9% as vegetables, 3.1% as maize, 2.8% as potatoes). This proves the poor differentiation of these crops in the early stages of development. In order to obtain higher accuracy, it is necessary to extend the time series of the radar data.
- 5) The nationwide area of potato cultivation is stabilized, 87.7%, and significant crop losses are observed in voivodeships with small farms, where they are grown on small plots.
- 6) A comparable legume cultivation acreage is maintained in Poland - 108.2%. Due to the relatively small cultivated areas in voivodeships, each change in the area is visible in a significant percentage change.
- 7) Due to the large acreage of grasses and grasslands in Poland and its voivodeships, no major changes were observed year on year - 90.5%.
- 8) The remaining recognized cultivation classes, due to the smaller areas, are highly variable. This variability is not visible at the Polish level, but is significant at the voivodeship level. In particular, the identification of permanent crops should be looked at more closely, i.e. plantations of fruit trees and shrubs and perennial strawberry cultivation.

**Figure 1. Sown area in 2019 and 2020.**



- b) An additional comparison of data on the cultivated areas in the Warmian-Masurian Voivodship was also made.

**Table 3. Sown area in the Warmian-Masurian Voivodeship**

Cultivation	2019			2020	
	R-CzBR_sg (June Agricultural Study)	ARiMR	satellite data	ARiMR*	satellite data
sugar beets	5 907	4 535	3 967	5 639	4 102
charlock	772	2 285	1 821	1 922	1 646
buckwheat	6 134	6 061	6 283	6 276	10 932
spring barley	33 936	24 156	16 440	22 548	18 098
winter barley	4 725	4 437	3 545	4 551	3 634
maize	52 633	74 010	75 623	82 030	87 047
cereal mixtures	42 857	24 467	25 078	21 378	21 729
oat	22 196	26 185	24 138	30 168	39 635
fruit tree plantations	1 177	1 624	12 102	1 276	9 364
fruit shrub plantations	922	1 793	13 649	1 502	7 664
millet	106	267	498	351	1 218
spring wheat	38 901	19 924	19 824	19 755	15 769
winter wheat	108 750	139 044	138 306	143 005	133 611
spring triticale	8 997	5 187	11 162	5 036	12 209
winter triticale	67 660	75 499	79 789	79 497	83 858
spring rape	1 430	3 138	2 824	2 408	296
winter rape	74 067	93 683	97 936	92 814	95 793
legumes	26 630	75 758	36 040	76 881	37 297
grasses and grasslands	368 483	567 987	561 945	572 199	545 313
strawberry	158	305	1719,07	272	2 228
tobacco	0	21	316	22	593
vegetables	1 178	1 605	1 902	2 894	2 044
potatoes	7 624	5 363	2 907	4 778	2 749
herbs and spices	949	2 419	523	752	387
rye	37 132	40 646	38 448	33 524	35 710
<b>Total</b>	<b>913 326</b>	<b>1 200 399</b>	<b>1 176 785</b>	<b>1 211 478</b>	<b>1 172 928</b>

Assuming satellite data of 2020 = 100, changes in the sown area are, for example:

- winter wheat from 93% to 123%,
- rye from 88% to 123%,
- winter triticale from 105% to 137%,
- winter rape from 98% to 129%.

\* non-final data, presented as of June 30, 2020.

- 1) The area data for warmian-masurian voivodeship was compared with the official results of the representative June survey (R-CzBR) of land use conducted by the Central Statistical Office in 2019. - according to the seat of the agricultural holding. The satellite reconnaissance described about 287 thousand ha (by 31.4%) more crops than in R-CzBR. This is due to the fact that the satellite recognition of crops is performed within arable land qualified for the single area payment by ARMA and covering the entire country. In addition, satellite recognition provides information at the level of not only voivodships, but also poviats and communes. Until now, the results concerning the area of agricultural farmlands and sown areas, based on sample surveys, have been generalised for agricultural holdings according to the seat of the holding or the seat of the holder. The data obtained on the basis of satellite imagery refer to agricultural areas within administrative borders. They may, therefore, differ from the areas presented up until now in a different perspective.
- 2) Additionally, the summary includes data from area applications submitted annually by farmers to the ARMA. The discrepancies in the sum of the ARiMR areas and the areas obtained from the Sentinel data result, firstly, from the fact that farmers' declarations do not describe all the plots (approx. 80% of the cultivated area in the voivodeship, 75% in Poland), and secondly due to the low spatial resolution of the Sentinel data, which results in the elimination of small plots.
- 3) The reason for the differences in satellite recognition of crops on 1 July 2020 for:
  - potato (shortage) and tobacco (surplus) is the use of too short time series of radar images. The time series covering the months of April-June includes only the initial stages of growth of these plants. Significant months for the identification of potatoes and tobacco are June - August, when the vegetation is fully.

- the second factor influencing the discrepancies is a small size of the plots, which again, due to the resolution of the satellite images (10 mx10m), are not identifiable.
- 4) There is too much variety within the class of fruit trees and shrub plantations (surplus). Plantations of trees and shrubs include many species and are characterized by higher vegetation and orderliness, which makes them distinguishable. Furthermore, the satellite data surplus is due to the fact that part of the permanent grasslands with trees and shrubs have been classified as fruit tree plantations.

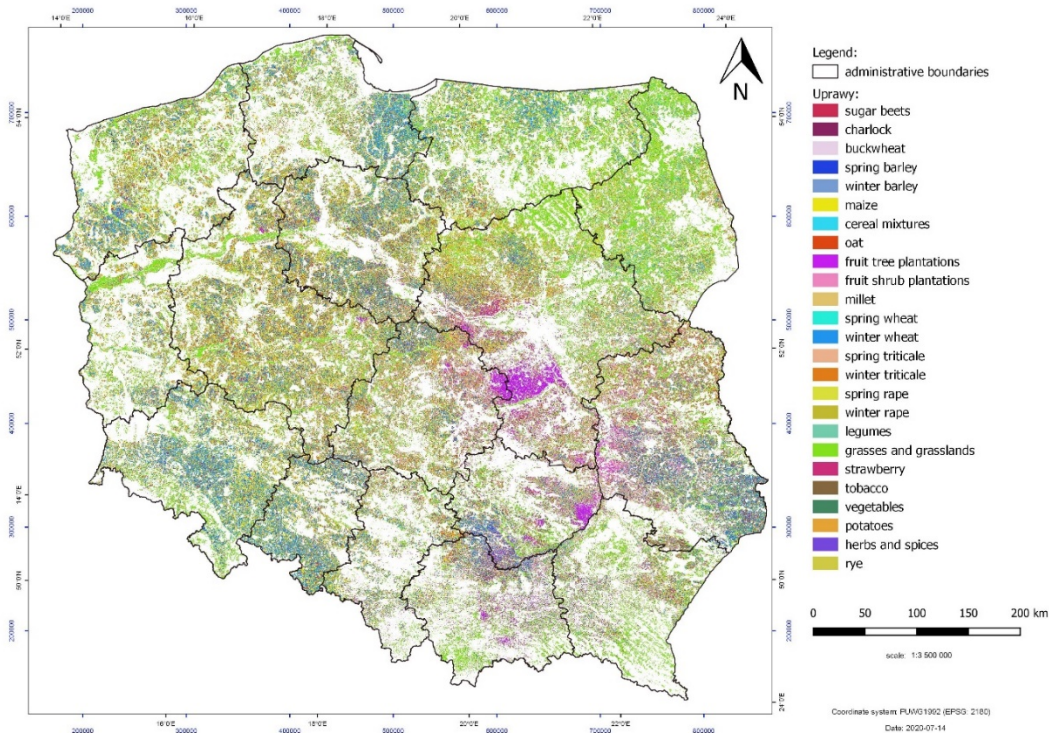
## Conclusions

Based on the conducted analyzes, it is concluded that the time series of Sentinel-1 radar data covering the months of April-June is sufficient to obtain satisfactory accuracy in identifying winter crops and some cereals and spring crops. In order to obtain a proper estimate of the other crops that develop in later months (maize, sugar beets, potatoes, tobacco and others) it is necessary to extend the time series. Low spatial resolution which excludes plots of small size remains the problem. The identification of classification errors for plantations of fruit trees and shrubs requires further analysis.

Statistics Poland and the Statistical Office in Olsztyn will continue intensive scientific and implementation works, conducted in cooperation with CBK PAN and IGiK, on the replacement of selected statistics on identification and monitoring of crops using satellite remote sensing. The Department of Agriculture has also established extensive cooperation with other public administration units (Agency for Restructuring and Modernization of Agriculture, Agricultural Property Agency, Ministry of Agriculture and Rural Development) and other scientific institutions so that in the future the data are presented at a lower level of aggregation (district, municipality), while the burden on the respondents and surveyors is simultaneously reduced and the quality of the presented results is improved.

**The map below shows a preliminary estimate of the main agricultural and horticultural crops in 2020 based on remote sensing methods.**

**Map 1. Preliminary estimate of the main agricultural and horticultural crops**



Substantive study

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### **Subject available in databases**

[BDL: Powierzchnia zasiewów](#)

### **Main terms available in the dictionary**

[Powierzchnia upraw](#)